Plunket (J. D.)

OZONE,

AND ITS

RELATIONS TO THE PUBLIC HEALTH.

BY

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OZONE, AND ITS RELATIONS TO THE PUBLIC HEALTH.

Ozone is a peculiar variety of oxygen, distinguished from ordinary oxygen by its greater weight, its peculiar and somewhat chlorous smell, its intensely active oxidizing powers and the ease with which it passes into common oxygen. Ozone, as it appears in the atmosphere, is in variable amount, differs in degree according to height, locality, temperature, electricity, etc. Mr. A. Beechan says, "it is more abundant on the sea coast than inland, in the west than in the east of Great Britain, in elevated than in low situations, with southwest than with northeast winds, in the country than in towns, and on the windward than on the leeward sides of towns." And Moffat states it is found in greater proportions when the mean daily temperature and the dew-point temperature are above the mean and the readings of the barometer are decreasing. From the records of the Scottish Meteorological Society, we find it "most abundant from February to June, when the average amount is 6, and least from July to January, when the average is 5.7. The maximum, 6.2, is reached in May, and the minimum, 5.3, in November." Commenting upon this, remark is made that "thus the maximum period occurs when evaporation is greatest, and the minimum when the condensation of aqueous vapor is greatest, a result in accordance with the conclusions arrived at by Dr. Berigny and M. Houzean. It thus also appears that it is most abundant where electricity is produced, and least so, or entirely wanting, where electricity is in least quantity, and where there is much decaying vegetable and animal matter." Ebermeyer says it is found most abundant in the air of open fields and in places of great atmospheric moisture. In the forests more is found in the upper strata of air, among the branches, than near the ground, owing, doubtless, to the absorption which occurs in the process of decomposition. According to Dr. Cornelius Fox the sources of ozone are—"The oxidation of metals, the decomposition of rocks, the germination of seeds, the growth of plants; the collision between air-currents of different degrees of humidity, proceeding from opposite quarters with one another, or with the earth; the evaporation which is continually proceeding from saline fluids, such as oceans, seas and lakes; the dashing and splashing, the smashing and crashing of the restless waves on the rocky coast—are all concerned in the simultaneous development of electricity and ozone." Kedzie says that ozone is to be "found where water by any means is 'pulverized,' *e. g.*, in the neighborhood of waterfalls," and in commenting upon this fact remarks that "this may possibly be explained by the fact, now well established, that ozone is soluble to a small extent in water ($\frac{1}{2}$ of 1 per cent.), and where water is thus converted into spray this dissolved ozone may be liberated." And he further adds: "It may at last be found that the delight which civilized man has ever taken in the thundering of the ocean surf, the roar of the waterfall, or the silvery tinkling of the fountain, has a deeper significance than the gratification of an esthetic taste, and that our sense of the beautiful is thus happily correlated with an important condition of bodily health."

The chemist has never as yet been able to isolate ozone. In its sensible properties it is a colorless gas, having a peculiar odor of phosphorus like that perceived during the passage of an electric spark, which caused Van Marum, who was the first to notice it in 1785, to describe this odor as "the smell of electricity,"—he believing electricity to be a material substance. This odor is so powerful that it is said that one part in a million of air can be distinguished by the sense of smell. It is one of the most powerful oxidizing agents known, oxidizing silver, mercury, iodine and many other substances immediately. It corodes cork, paper, animal membranes, caoutchouc, and other organic substances.

It is nature's great disinfectant and deodorizer, uniting most readily with the gases which arise from decaying vegetable and animal matter, and by depriving them of their noxious qualities, serves as a great purifier of the air. Its importance arises from its intense activity rather than its amount, for the maximum quantity of ozone in the air, Howzean informs us, never exceeds $\frac{1}{700000}$ of its bulk, and often is entirely wanting.

What relation this intensely active and exceedingly interesting agent sustains to animal life, is the aspect of the subject which must interest us most, and when the additional fact is stated that the influence which ozone exerts upon health and disease is still an undetermined problem, it cannot fail to prove an active stimulus to our efforts in aiding, so far as possible, by the accumulation of data and otherwise, the elucidation of a question which apparently promises so much. Ozone, in its effect upon the mucous membranes, especially of the respiratory passages, is that of a powerful irritant, when breathed in any concentrated form, which fact led to the suggestion of its possibly being in some way connected with, if not the immediate cause of, epidemics of influenza and catarrhs. Schœnbein observed at Berlin, during an epidemic of influenza, a considerable quantity of ozone in the atmosphere. Dr. Pietra-Santa has also shown that when influenza prevails the ozone-papers show lively reactions. Prof. Charles N. Hewitt, of Minnesota, in a paper read before the American Medical Association in 1871, says: "The peculiar atmospheric condition which is the cause of our epidemic influenza is now attracting deserved attention, and it is hoped that the recent offer of a prize by the State Medical Society may result in investigations of practical value. This much is known: that when influenza is *markedly* epidemic, zymotic diseases diminish in severity, become less frequent, and disappear. Though as yet no sufficient tests have been used, the majority reporting (judging from its action on 'civic miasm,' which seems that of an oxidizing agent, and from reports of its study elsewhere), believe it to be ozone." A residence among the balsamic odors of the pine has long been esteemed of benefit to the pulmonary invalid, which practical fact finds ready scientific explanation in the statement made by Dr. Schreiber, of Vienna, that "the turpentine exhaled from pine forests possesses, to a greater degree than all other bodies, the property of converting the oxygen of the air into ozone." Dr. C. Dennison, of Colorado, says "that the excess of ozone noted during the spring months on the plains came proportionately late in the season the higher up the mountains the observations were made." This statement, no doubt, will be fully confirmed by the recorded observations of ozone now being made in Tennessee, regarding the valleys as compared with the plateau of the Cumberland mountains of our State, which may serve as a profitable indication to the invalid, the delicate and overworked, of the special advantages of going into yet higher regions during the progress of the summer season, where, consonantly with the increase of ozone, can be enjoyed the cooler temperature and purer atmosphere which elevation always insures.

Beside diseases of the nose, throat and pulmonary structures, other maladies have been suggested as in some measure due either to the presence or absence of ozone in the atmosphere, or aggravated or mitigated by it: for instance, Billard, Wolf, Boeckel and Strambes agree that the cholera in Strasbourg, Berlin and Milan coincided with the absence of ozone, and that it reappeared on the decline of the disease—an important observation to confirm, should cholera visit Tennessee during the approaching summer, as is now apprehended by many of the best informed it may.

Hon. Frank H. Mason, United States Consul at Marseilles, France, in an interesting report to the Department at Washington, D. C., bearing date of September 30, 1884, upon the recent epidemic of cholera which occurred there, under the sub-heading, "Some Teachings of the Epidemic," makes the following statement: "It is now a well established fact that the presence or absence of ozone in the atmosphere has a marked effect upon choleraic conditions.

"It was noted early in the present epidemic that there was a marked deficiency of ozone in the atmosphere of Marseilles, and means were adopted to supply this deficiency at the Pharo Hospital, in this city, by the usual means of an electrical apparatus.

"The process of negatively electrifying the oxygen of the air on a sufficiently large scale for practical sanitary purposes is always difficult, but sufficient was done and observed in this direction to fully establish the following facts:

"1. That the whole period of the cholera epidemic has been marked by a notable deficiency of ozone in the atmosphere of Marseilles.

"2. That in the wards of the Pharo Hospital, where artificial ozone was provided, the death-rate was considerably diminished.

"3. That the days of greatest fatality in respect to the number of both new cases and deaths were those during which the proportion of natural ozone in the air was smallest.

"4. That the setting in of a southwest wind, which, although warm, brought an increase of ozone to the local atmosphere, was, in every instance, followed by an immediate and marked decrease in the death rate and the number of new cases reported."

Cholera has appeared twice in epidemic form at Fort Riley, in Kansas, and Dr. W. A. Hammond is quoted as authority for saying that while the epidemic continued at that post, the air was dry and contained no ozone, the occurrence of a very severe thunder storm put an end to the epidemics in both instances, and ozone at once reappeared in the atmosphere.

The wonderful oxidizing power of ozone has caused its artificial production to be suggested for ordinary disinfecting purposes. On November 21, 1878, I had the honor of reading a paper before the American Public Health Association on "The Disinfection of Sewers by Ozone," suggesting a simple and cheap devise for its manufacture and application in "the disinfection of sewers and other sources of mephitic gases." In this connection, Dr. Fox in a late work suggests that "ozone should be diffused through fever-wards sick-rooms, the crowded localities of the poor. Its employment is especially demanded in our hospitals, situated, as they mostly are, in densely populated districts, where the atmosphere is nearly always polluted by re-breathed air, decomposing substances and their products, and where no ventilation can be fully effective." Continuing, he further says: "If practicable, it would be highly advantageous to direct streams of air, artificially ozonized, into the fever and cholera nests of our towns." Ozone may be easily disseminated through public buildings, theaters and other confined atmospheres, where numbers of people are accustomed to assemble, in order to maintain the purity of the air.

Curious and interesting as is the subject of the presence and effects of ozone in its manifold applications, the obscurity which envelops still the whole subject requires yet many thousands of accurate observations before definite deductions can be profitably attempted. Appreciating fully this fact, so far as ozone bears relations to human health and disease, the public health men of Tennessee have been long anxious to see inaugurated some plan by which ozone observations could be secured regularly by competent observers in different places throughout the State. With this view, the Nashville Board of Health acted formally and early, as will be seen from the following extract taken from the report of J. Berrien Lindsley, M. D., Health Officer, as published in the Third Report of the Nashville Board of Health, 1878:

"At a meeting of the Board, held June 20, 1876, it was, on motion of Dr. J. D. Plunket,

"*Resolved*, That the meteorological observations made by the United States Signal Service here and at other points are of the greatest value to the physician, as well as to the agriculturist and merchant.

"*Resolved*, Also, that the value of the observations here, in a sanitary point of view, will be greatly increased by proper registrations of the variations of ozone in the atmosphere.

"*Resolved*, That the Director of the United States Signal Service be petitioned to supply the Nashville station with the necessary means for such registration.

"Adopted, and the Health Officer was directed to transmit a copy of them to the Department at Washington, D. C. In response, the following was received:

"WAR DEPARTMENT, OFFICE OF THE CHIEF SIGNAL OFFICER,
DIVISION OF TELEGRAMS AND REPORTS FOR THE BENEFIT
OF COMMERCE AND AGRICULTURE,
WASHINGTON, D. C., July 10, 1876.

"J. BERRIEN LINDSLEY, M. D., *Health Officer*, *Nashville*, *Tenn.:*

SIR:—By direction of the Chief Signal Officer of the Army, I have the honor to acknowledge and answer your communication of the 6th inst., communicating resolutions of the Board of Health of Nashville relative to special observations for the benefit of the public health.

This has frequently been considered by this office. What it does in the domain of climatology is in addition to its regularly defined duties, and it is quite certain that to enter upon the kind of observations to which you refer would require a very liberal construction of the laws and orders relating to this service. It would, however, afford this office satisfaction to enter upon the additional field of usefulness, if authorized and provided with facilities, but every new observation would require more money and more force, whereas it seems probable that Congress will diminish both the money and force heretofore allowed, thus rendering necessary an abandonment of work now performed. The proper course for the Board of Health would be to address to Congress resolutions showing the importance of increasing the appropriations and force of the Signal Service, and send them to the proper Senators and Representatives, also one copy to this office, that it may be referred to. The present resolutions, however gratifying as showing the appreciation of the work of the service, are not practically useful for the immediate object the Board has in view, as the facilities must be given by Congress before they can be used to comply with the request of the Board. Respectfully yours,

GARRICK MALLERY,

Captain and Brevet Lieut. U. S. A., Acting Signal Officer and Assistant.

"Acting upon the above, at a meeting of the Board held July 20, inst., it was unanimously resolved, that the following memorial be sent to the Senators and Representatives in Congress from Tennessee:

"The Board of Health of the City of Nashville do hereby respectfully memorialize the Senators and Representatives of the State of Tennessee in Congress assembled, as follows:

"WHEREAS, By an Act of Congress, approved February 9, 1870, it was made the duty of the War Department to make, register and publish, by telegraph and otherwise, an extended series of meteorological observations; and,

"WHEREAS, The United States occupy climates and areas peculiarly fitted for solving the great problems connected with epidemics and public health, as well as intricate questions connected with the physical sciences which Franklin and Morse did so much to develop; and,

"WHEREAS, This invaluable series of observations is utterly beyond State and individual effort, and yet is alike beneficial to all the individuals and States composing the Union:

"Therefore, we do earnestly hope that your influence and vote will be so used as to increase and extend, and not cripple the singularly beneficent and peaceful workings of this small portion of the national army.

What Congress did regarding this Bureau was, in a word, to let it alone—no increased facilities were allowed, it, and up to now, as an organization, it has attempted no ozone observations that we are aware of.

Dr. Albert C. Ford, United States Signal Service observer stationed at Nashville, upon the suggestion of the Chairman of the Committee on Climatology of the Local Board of Health, began the taking of ozone observations in the spring of 1877, but soon after, in consequence of failing health, abandoned it. These, it is believed, were the first ozone observations ever made in Tennessee. No further effort was made, so far as we are informed, to ascertain the amount of ozone in the atmosphere of our State until the fall of 1884, when a special Committee on Ozone was raised in the State Board of Health, and upon the request of its Chairman, L. N. Jesunofsky, United States Signal Service observer, stationed at Nashville, began on October 1, 1884, to make regularly two daily observations on ozone. With the view of obtaining similar observations throughout the State, the following correspondence indicates what steps were taken and progress made:

NASHVILLE, TENN., September 29, 1884.

HON. A. J. McWHIRTER, *Commissioner of Agriculture, Statistics and Mines, and Director of State Weather Service, Nashville:*

DEAR SIR—Having watched with much interest and pleasure the practical workings of the State Weather Service, as organized by you throughout Tennessee, I now, in behalf of the State Board of Health, request that you take one step further in advance, and add one other column to your present form for reports, in which shall be recorded the tri-daily observations of ozone, as may appear at the different stations in the State.

Ozone, as you know, is Nature's great deodorizing and purifying principle that oxidizes the emanations from decomposing animal and vegetable substances, with which the air is unceasingly being contaminated, thus rendering them innocuous, and fitting the atmosphere for the further sustenance of animal life.

An agent, then, of such amazing power, and present in such variable amount in the medium which envelops us every moment of our lives, cannot, it would seem, be other than most significant in its influence upon public health.

It is in this relation that the information sought is most desired, for, as yet, we have not a sufficient amount of carefully observed fact to serve as a basis for any generalization of the special relations of ozone to disease.

To the end of supplying this great want, by having the facts in regard to ozone in Tennessee gathered up and collated, and thereby serve indirectly as an inspiration to other States and communities to do likewise, this communication finds its apology; for then, by a careful and conscientious comparison of these facts, with the regional and seasonal history of disease, we may be enabled to arrive at conclusions which shall be more than unfounded assertion or imaginative hypotheses.

Should you be pleased to co-operate in the manner suggested, this Board will furnish to all observers whom you may designate, the means by which the observations can be made, accompanied by such instructions as may be necessary for the easy comprehension of any.

I am, sir, very respectfully and truly yours,

J. D. Plunket, M. D.,
Chairman of Committee on Ozone of State Board of Health.

Nashville, Tenn., October 6, 1884.

Dr. J. D. Plunket, *Chairman of Committee on Ozone of State Board of Health, Nashville:*

Dear Sir—Your communication of September 29th, asking the co-operation of the Weather Service Department of this Bureau, in getting the observations of ozone throughout the State, has been received.

This Bureau will, at all times, cheerfully and heartily co-operate with the State Board of Health in anything pertaining to the welfare of our State and the advancement of the physical or material interests of its citizens.

Your suggestions regarding the mode of taking the observations will be presented to our voluntary observers, and their assistance invoked in the work.

Very respectfully yours,
A. J. McWhirter,
Commissioner, and Director State Weather Service.

In due time notice was received from the Director of the State Weather Service that each observer of his department entered heartily into the request, and upon receipt of material and instructions, they would cheerfully begin the work. At once there was prepared and forwarded, through the office of the Director of the State Weather Service, to each observer, a copy of the following:

INSTRUCTIONS FOR

MAKING AND RECORDING OZONE OBSERVATIONS,

Issued to the volunteer observers of the Tennessee Weather Service

BY THE STATE BOARD OF HEALTH.

1st. For the present, only two observations in each twenty-four hours are called for, viz.: a "Day Observation," to be taken from 7 A. M. to 2 P. M., and a "Night Observation," to be taken from 9 P. M. to 7 next morning, and recorded in the line of report for the day on which the test paper was put out.

2d. The observations are taken by means of Schœnbein's test-paper, and the result determined by comparing the test-paper employed with the ozone-scale, which, in each instance, must be that furnished by the State Board of Health.

3d. Each observer is requested to give timely notice of the exhaustion of his supply of test-paper, that no break in the observations may occur, and also to preserve the stock of test-paper in a closed bottle or jar, in a dry and dark closet, because sunlight will form ozone and color the paper so as to destroy its value as a test. Colorless test-paper only must be used in measuring ozone, and it should be exposed where it will not be subject to action of sulphurous acid gas, or very near where coal is burned. Even the fumes of burning sulphur from a single match, held near the test-paper may bleach it after having been colored by exposure.

4th. In making an observation, take a single strip of the test-paper furnished you, dip one-third of the paper in pure water, and pin it up in a place screened from direct sunlight, but freely exposed to the air, and diffuse daylight. An ordinary spring clothes-pin, properly fastened in position, is a convenient article to hold the test-paper during the exposure. After exposure for the time stated above, dip the paper in clear water, immediately compare it with the ozone-scale, and enter in the proper column of report the figure on that portion of the scale which most nearly corresponds in color with the test-paper used. If there is no discoloration of the test-paper, no ozone is present, and a cipher should be entered on the record for that observation.

5th. In deciding the amount of ozone for any observation by comparison of the test-paper with the ozone-scale, the *prevailing* color of the test-paper should be taken, and not the exceptional spots or streaks. The observation should be made and recorded from the side of the test-paper most darkly colored, whether front or back.

Also a copy of the lithographed "ozone scale" which is to be found upon the following page, and a sufficiency of test-paper, prepared after the formula of Schœnbein, to last each observer for four months. Observations were begun simultaneously upon December 1, 1884, and at this time there are twenty-eight observers actively engaged in making ozone observations in Tennessee, whose names and post-office addresses are as follows:

Geo. W. Robinette, Quarter, Claiborne county.
Jno. A. Cody,* Knoxville, Knox county.
Foster Clarke, Maryville, Blount county.
David Hart, Careyville, Campbell county.
S. E. Franklin, Sunbright, Morgan county.
J. T. Cowden, Grief, Bradley county.
B. L. Goulding,* Chattanooga, Hamilton county.
T. L. Denny, Cookeville, Putnam county.
W. K. Patterson, Jr., McMinnville, Warren county.
S. P. Fergusson, Riddleton, Smith county.
Chas. F. Vanderford, Florence Station, Rutherford county.
L. N. Jesunofsky,* Nashville, Davidson county.
Prof. J. M. Safford, Vand. Univ., Nashville, Davidson county.
J. A. Laughlin, Hurricane Switch, Maury county.
Rev. C. F. Williams, Ashwood, Maury county.
Samuel Stewart, Clarksville, Montgomery county.
W. J. Inman, Kingston Springs, Cheatham county.
Frank Winship, Pulaski, Giles county.
Sam'l Donaldson, Dickson, Dickson county.
Dr. Cicero Buchanan, Waynesboro, Wayne county.
H. R. Hinkle, Savannah, Hardin county.
Dr. M. D. L. Jordan, Milan, Gibson county.
A. S. Currey, Trenton, Gibson county.
E. P. McNeal, Bolivar, Hardeman county.
Louis Hughes, Dyersburg, Dyer county.
D. B. Cummins, Somerville, Fayette county.
Dr. T. W. Roane, Covington, Tipton county.
D. T. Flannery,* Memphis, Shelby county.

A number of other names are expected to be added to this list soon.

The observers will make their reports to the Director of

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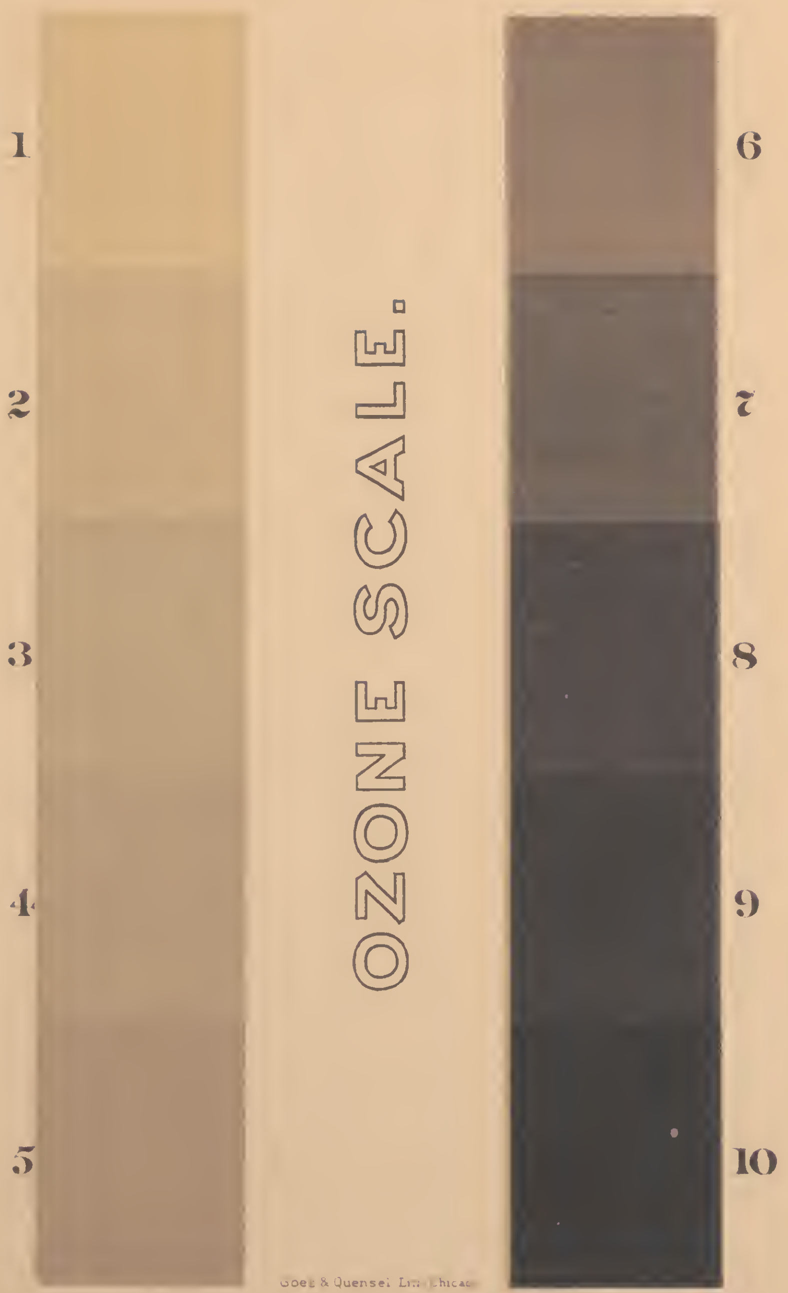
* U. S. Signal Officers.

OZONE SCALE.



Goes & Quensel Lith. Chicago

the State Weather Service, and he will embrace the same in tabular form in the monthly printed report issued from that office. Thus will be accumulated and preserved the data regarding ozone in Tennessee, which will, at the proper time, be analyzed, arranged and reasoned upon by your Committee on Climatology with the view of obtaining, if possible, practical deductions, especially so far as ozone may appear to be related to questions affecting the public health.

The Committee on Ozone had reprinted and distributed among the observers of the State Weather Service, and others interested in the subject, the two following instructive and valuable papers, the one by Dr. Mulvany, and the other by Dr. Nicholson.

OZONE IN NATURE.*

ITS RELATIONS, SOURCES AND INFLUENCES.

A Paper read before the British Meteorological Society, June 16, 1880.

BY J. MULVANY, M. D. R. N. (ENGLAND.)

Ozone, since its discovery by Schœnbein, has been to the scientific world the subject of incessant study and observation; by medical men especially it has been regarded with the deepest interest, for experiment has shown artificially prepared ozone to be endowed with great energy of action, and to be adapted by its physical atributes and chemical affinities to play a very important part in the chemico-vital processes of the system, and in the purification of the atmosphere. And as it was seen to stimulate the respiratory and circulatory organs, and when inhaled in excess, to irritate the mucuous tract over which it passed, and moreover to be readily absorbed by the blood, in which it liberates oxygen, checks incipient putrefaction, and replaces it by restored coagulability, and to so elevate in the scale of oxidation the chemical formula of the products of retrograde metamorphosis, as to render them more facile of elimination, atmospheric ozone came to have ascribed to it the most varied offices and influences, prophylactic, sanitary, morbogenetic, etc. But the part it plays in the economy, and how far it ministers to health or promotes disease, should be determined by observation alone. And as it is rarely met with dissociated from meteoric and other subtle agencies which often are sufficiently powerful to modify the extent of its appreciability or to disturb the functional harmony of the system, a careful elimination of the effects of these one by one is obviously necessary for the differentiation of its action (*per se*). For the acquisition of such an accumulation of data as this requires, the naval medical officer has peculiar facilities. In the observations from which the present report is epitomized are embraced the varied conditions of climate met with between the Doggerbank on the north, Madagascar and the Falkland Islands on the south, and from 96° long. west to the same number of degrees east, and the modifications which ozone underwent from cold, heat, humidity, pressure, geographical position, configuration, soil, contiguity to a desert, a jungle, or a marsh, etc.; also, the corresponding sanitary conditions on shore and afloat. As the investigation of its effects may be advantageously preluded by that of its relations, I will proceed to the consideration of these latter, commencing with temperature.

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* Michigan State Board of Health, Report 1880, page 277.

TEMPERATURE.—From experiments in the laboratory, when a high temperature is seen to break up the peculiar grouping of the molecules of oxygen which constitutes ozone, and restores them to their bulky and less active state, it has been supposed that a much heated condition of the atmosphere is inimical to ozonization, and hence probably it has come to be axiomatically formulated, that the curve of the ozone is in the inverse ratio to that of the temperature. Strictly speaking, this rule holds good where a high temperature with a minimum humidity obtains; but this is too seldom witnessed in nature to constitute a rule; so narrow is its applicability that it might rather be classed as an exception. For as the atmosphere becomes rarified by heat its capacity for taking up and holding water in a state of vapor is correspondingly exalted, and consequently a high temperature, except under peculiarities of locality to be hereafter alluded to, is always associated with a high humidity, and humidity is favorable to ozone. But, regarding temperature alone, it will be seen from the following table that the temperature of the atmosphere as met with in nature bears *no* relation to its ozonic condition:

DATE.	PLACE.	TEMPERATURE IN SHADE.			Ozone. Mean.
		Minimum.	Maximum.	Medium.	
January, 1867 ...	Lake Erie.....................	14 below zero.	32°	9°	2°.5
January, 1868 ...	" "	16 " "	27	5.5	2.5
April, 1868	" "	31 above "	52	41.5	3.0
March, 1870	Harlar Hospl., Heaths	26 " "	61	41.5	2.0
August, 1872	Mozambique	70 " "	90	80	1.3
May, 1872	East Africa	78 " "	88	83	9.5
November, 1373	Trincomalee, Ceylon..	75 " "	86	80.5	10.0
September, 1871	Persian Gulf..............	83 " "	104	90	7.5

HUMIDITY.—When a high humidity accompanies a high temperature, the rule, with many exceptions, however, is that ozone is also high, and with a similar temperature and a low humidity ozone is scanty. This is illustrated by the following figures:

DATE.	PLACE.	TEMPERATURE.		HUMIDITY.		Ozone.
		Minimum.	Maximum.	Per Cent. of Saturation.	Vapor Tension.	
October, 1865.....	Santa Maria...	78	85	77	0.723 in. Mercury	5
August, 1871	Persian Gulf...	87	114	79	1.223 "	6
July, 1873	Zanzibar	70	84	78	0.854 "	6
May. 1873	Muscat, Ar'bia	94	99	28	0.514 "	a trace
September, 1872	Madagascar ...	72	97	51	0.570 "	2
January, 1877...	Falkland Isl's	33	61	74	....	10

Than this relation of ozone to heat and humidity, nothing is more calculated to impress us with the benignity and prescience of the design which causes an augmentation of ozone, when for the maintenance of a pure atmosphere it is most required, that is, under the conditions of heat and humidity in which organic compounds are most unstable and putrefy with the greatest rapidity. The association of ozone with vapor in a high degree of tension, though not definite in its relation, is nevertheless so constant that whatever tends to augment the latter will have a similar effect on the former. This is well exemplified in the case of winds.

WINDS.—The hot, dry winds that sweep over the arid rocks of Beloochistan, or the thirsty sands of Arabia, rarely contain more than a mere trace of ozone when they arrive at the seaboard. In the Mozambique Channel, which the southeast trade winds reach after having their moisture wrung out of them by the high central plateau of Madagascar, ozone is very scanty indeed. At Trincomalee, during the southwest monsoons, which reach it after being filtered through the jungle, a great paucity of ozone is observed in the lower atmospheric strata. But on the contrary, wherever the breeze reaches after sweeping over a large tract of sea, ozone and humidity are usually abundant. Hence, it appears to be through the nature of the surface over which they blow that winds influence the ozonic condition rather than by their force or direction.

AREA.—The area over which winds pass, if homogeneous, tends greatly to augment or diminish ozone, water producing the former effect, land the latter, the difference between the west and east coasts of Mahe, in the Seychelles Islands, being one to two degrees less on the leeward side. In passing through the Bay of Bengal, January, 1874, with the northeast monsoon blowing, I got at the port of departure, Trincomalee, the maximum shade; at the Andaman Islands (Port Blair), it amounted to only 2; and at

Rangoon, or the *embouchure* of the Irrawaddy, it barely reached 1.

CLOUDS are favorable to ozone. In the Indian Ocean, where, during monsoon weather, heavy murky piled clouds are often met with, the atmosphere is as a rule strongly ozonized; whereas, when the sky has been bright, blue, and cloudless for a week, it usually averages 1.5 to 2.

ATMOSPHERIC PRESSURE, humidity apart, does not appear to exercise any influence whatever over the ozonic condition; but taking 29.90 for the intra and 30.00 for the extra tropical standard, the greatest abundance coincides with the readings below these.

RAIN sensibly augments the ozonic condition; if there have not been a trace of coloring for several days a single shower is often observed to effect an immediate coloration. I once observed this under circumstances entirely unique. On the passage to Seychelles, in June, 1873, there was an abundance of ozone from a few days' sail off the Arab coast to within a short distance of the Equator. I did not observe the faintest trace of it during the 18th, 19th and 20th, although the sky was cloudy, the air hot and humid, and the wind high and squally; but during the night of the 20th it rained heavily in showers, and the next morning the test-slip was colored to the utmost. As we had during the period of negation crossed the "Line," it struck me that the peculiarity of the negation might be owing to an antagonistic influence being exercised in the equatorial belt by the *horizontal magnetic force of the earth*, but subsequent experience showed this conjecture to be erroneous. It, however, led me to investigate the relative abundance of ozone in the north and south latitudes, but my data are not sufficiently copious to admit of deductions. During 250 days south of the Equator in the Eastern Hemisphere, the ozone averaged 3.5, and during 450 days north of it, 6.5. Since then I passed over two years south of the

Equator, in the Falkland Islands, and never found the ozone under 10.

Squalls.—A squall without rain produces a very slight degree of coloration, but the increase resulting from a rain-squall is decided. A thin steady mizzle of a whole day's duration will not show more color than a strong rain-squall of two hours. This led me to believe that the *phosphorescence* of the tropical seas might be a source of ozone, and that the difference between the thin mizzle and the smart shower might be owing to the greater momentum of the latter penetrating the sub-surface waters and agitating the myriads of noctiluca which have their habitat there, and thus cause them to light up their tiny lamps and thereby generate ozone; but I failed to corroborate this by experiment, and subsequently I found reason to believe that rain simply acts as a vehicle, and that the difference in effect between the mizzle and the smart shower consists in the latter coming from a greater height—but I will return to this presently.

Altitude.—When, from any cause, the ozone of the lower atmospheric strata gets used up, that from the higher does not appear to diffuse readily into its place, and hence it occurred that I was often able to obtain a high degree of ozone at the masthead when the air on the upper deck gave hardly a trace. At Trincomalee, 1873, during the south-west monsoon, the greatest amount of ozone was always obtainable at the flag-staff, 175 feet high, next at the top of the mainmast of my ship, then on deck, and least in the village. The wind, before reaching the deck, got filtered through the jungle. The top of the mainmast reached a stratum only partially filtered, and the flag-staff towered above the tops of the tallest trees. The effects are seen in this tabular form:

TIME OF EXPOSURE.	OZONE OBTAINED AT		
	The Flag-staff, 175 ft. high.	The Maintop, 120 ft. high.	On upper deck.
From 9:30 A. M. to 9:30 P. M., October, 1873.........	9	7	2
From 9:30 P. M., 6th Oct., to 9:30 A. M., 7th Oct......	5	5	2
	14	12	4

EVAPORATION would seem to be indicated by the close relation which exists between humidity and ozone as a source of this latter; but although it contributes towards its *genesis de longue main*, it is not by the act of evaporation that ozone is produced; for when evaporation is greatly impeded or checked by the elastic force the atmospheric vapor has acquired, the ozone may be abundant, and *vice versa*.

GENESIS OF OZONE.

But though not a direct factor, evaporation appears essential to its formation, for, dormant in the vast quantities of vapor which ascend from the surface of the tropical seas at or beyond 85° F., it throws into the upper strata prodigious quantities of force in the condition of latent heat, which, as it becomes liberated by rarefaction and radiation, swells out the lower strata and approximates them to the upper; while at the same time, if one may judge by the strong electricity which accompanies the precipitation of vapor without rain on a clear summer's evening, when a cloudless sky permits free radiation, the liberation of heat, the radiation and condensation in the upper regions similarly affect the liberation of electricity, and so augment the electric tension of the lower strata that the insulating medium (Quetelet) diminished in resisting power by the bulging upwards of the strata below it, is no longer able to keep the electricities apart, and in the act of uniting the paramagnetic oxygen gets acted upon and condensed into ozone. If this supposition be correct, the action of rain, etc., is easily understood. Rain would simply act the part of a vehicle and bring us ozone from the upper regions, and the difference between a smart shower and a drizzle would be occasioned by the former coming from a greater height, as attested by the greater velocity and momentum it acquires in falling in virtue of the accelerating force of attraction. It is probably owing to the absence of this vehicle that no appreciable increase of ozone is occasioned by the noiseless flash-lightning so common in autumn and in the tropics. It cannot be doubted that flash-lightning is identical in nature with the terrific corruscations, which, accompanied by thunder and rain, render the formation of ozone appreciable by the olfactories. But there is every reason to believe that the former occurs at a much higher altitude, at such a distance, in fact, that its accompanying sound cannot reach us. By the vehicular function of the rain drops the favorable influence which clouds (rain spherules in a state of flotation) exert, is easily understood.

OZONE—ITS RELATION TO DISEASE, AND ACTION ON THE SYSTEM.

MALIGNANT CHOLERA.—Scanty ozone, or its total absence for a period, was supposed by Steimer and others to be the *primum mobile* of malignant cholera, and Armand Isbert looked for its efficient cause in a similar condition of ozone combined with the exaltation of temperature, great humidity, and stagnation of the atmosphere. During the cholera epidemic which swept the East in 1871, and paid a visit to H. M. S. "Magpie," the ozonic condition presented no peculiarity either in point of paucity or abundance; and it is not a little remarkable that when the heat reached its maximum and brought in its train great humidity and arid stagnation, the cholera entirely ceased, but reappeared as soon as the great heats were over, and the morning and evening atmospheric circulation became again brisk. The following table will show the leading features of the two cholera periods, and the intervening healthy interval in the Persian Gulf in 1871 :

First Cholera Period, July 1 to July 20.	Healthy Interval July 20 to Aug. 28.	Second Cholera Period, August 28 to October 1.
Wind, N. Force, 2 to 6	No Winds	Variable, 2 to 6.
Temperature, 75° to 93	89° to 104°	80° to 94°. Under double awn'gs.
Vapor tension, 0.654 in	1.106 in	1.015 in.
Saturation, 50	84	70.
Ozone, 4 to 9	2 to 6	2 to 6.

In both these periods it would be impossible to suppose that ozone was in any way connected with the origin or prevalence of the disease, and it is quite clear, and was recognized by every one on board, that its temporary cessation was occasioned by the intense heat.

Consumption has been ascribed by some to a deficiency, by others to the opposite extreme, of ozone. Amongst those who held the latter was its illustrious discoverer. The disease is met with under circumstances unfavorable to the presence of ozone, viz., where overcrowding occurs, and the ozone not only gets used up, but the atmosphere gets vitiated by exhalations from the skin and lungs, and it is rather to this latter pollution that the disease must be ascribed than to ozonic deficiency. In Nassua, N. Providence, the sanitarium of the West Indies, the disease commits the most fearful ravages amongst the negroes, who sleep in close, small, windowless huts, stretched out *ventre a terre*, but spares the whites, who sleep in large, well ventilated apartments. In Seychelles it is also met with amongst the blacks, who resemble their brethren of the West Indies in their domestic arrangements. Amongst the Sackalavas, Arabs, and negroes of Madagascar, where the ozone is hardly ever above 2 or 4, I never met a single case; but their houses are simply constructed of reeds, or if of mud, the gables do not reach to the roof, so that free ventilation always obtains. In the Indian Islands, where, during certain months, an excess of ozone is the rule, and in the Falkland Islands, where an excess is constant, consumption is hardly ever met with—so that I do not believe ozone tends, either by excess or the opposite, to promote the disease. But a cure being once established, I believe an ozonized atmosphere to be more suitable than one where there is but little.

Sloughing ulcer is common in Mozambique, but so it also is in Seychelles, and there it was found to depend on the presence of a parasite intermediate in shape between the chigoe (jigger) and the cimex lectularious.

EXCESSS OF OZONE.

The diseases I have met with most frequently in association with excess of ozone are simple fevers, functional heart disorders, and dysentery, but I have never found reason to think it had any casual agency in their production.

INFLUENCE ON THE PROCREATIVE FUNCTIONS.

The only influence I have been able to obtain satisfactory indications of ozone exercising on the human system, is, that which it appears to exercise on the procreative functions; whether it exalts the vitality of the Graffian vesicle, stimulates the inherent developmental force of the seminal corpuscles, increases the activity of the generative organs in the male and female equally, I know not; but it certainly appears to increase the chances of fecundation, for I have found that births are few where ozone is scanty, and numerous where abundant. In a Sakalava or negro village, on the west coast of Madagascar, the most striking features are the scarcity of children, and the great number of old men and women. The negroes have lost that special aptitude for augmenting the census that characterizes them in the Antilles, and even the neighboring islands Johanna, Seychelles and Zanzibar. But the Malagash negroes breathe a scantily ozonized air. On the north side of Cuba and Jamaica large families are the rule. On the east coast of Central America multiple births are not uncommon. *La calle de los siele ninos,* "the street of the seven children," perpetuates in its name the fecundity of a Santa Martana. In July and August, 1867, babies came in platoons along the shores of Lake Erie as a result of the high ozonic condition of the Indian summer months of the year before. At Trincomalee, in Ceylon, the most positive evidence of this peculiar influence is obtainable; the village is low, but little above the sea level, is open to the sea on the northeast, and has the jungle to the southwest. From May to September the southwest monsoon blows over the island, and in passing through the jungle gets robbed of its ozone. From October to April the northeast monsoon blows over the Bay of Bengal and arrives at the village laden with ozone. During April the winds veer from northwest to southwest, and ozone is in fair proportion. Here is a suitable field for testing its influence. For this purpose I overhauled the baptismal registers for two years kept by the Roman Catholic priests, because their religion requires a child to be baptised as soon after birth as possible. Then I had access to the public register. Then I examined the meterological records kept at the flag-staff, and comparing the color slips, showing the ozone on board, found the proportion of ozone in the village to that of the flag-staff, with the result that during the southwest monsoon, viz., from May to September, the ozone in the village was 2½; from October to April 8. And the corresponding conceptions were 57 and 100, viz., ozone 2.5, conceptions 57; ozone 8, conceptions 100.

ATMOSPHERIC OZONE,*

AND THE BEST METHODS FOR ITS OBSERVATION.

BY A. W. NICHOLSON, M.D., OF OTISVILLE, MICH.

Such experiments as I have conducted have principally been made with Schœnbein's test of iodide of potassium and starch, that being considered the most reliable test for the presence of ozone.

While the many observations taken by those interested in studying the relation of ozone to prevailing disease are of great value, it cannot be denied that errors creep in and render many *single* observations of little value.

Often an apparent decrease in atmospheric ozone will exist when an increase will be the actual condition. There may be an error by excess of moisture, by an exposure of the test-paper to too great velocity of the wind, etc.

It has been stated that ozone is absent in dwellings. While this statement is not incompatible with any theory concerning the relations of ozone to conditions of health or disease, it is not altogether truthful; for many conditions obtain in the in-door atmosphere that occasion error in the result of a given observation, and, notwithstanding the presence of these conditions, the presence of ozone in dwellings has often been discerned by the writer and by others.

It is true that the results of experiments concerning the amount of ozone in the air above swamps are often negative, yet here there is, without doubt, a source of error in an excess of moisture.

The principal experiments conducted by myself have been to determine the presence of ozone in dwellings, and the probable influences affecting such tests; to determine the relative amount of ozone in pine forests, compared with observations taken in the open country; to ascertain the relative amount of the same element by experiments conducted in the smoky atmosphere in proximity to a large number of "pits" for the manufacture of charcoal; to estimate the amount of ozone existing over swamps; and to compare the amount of the same by the exposure of tests at the differing elevations of four feet and fourteen feet from the ground. Experiments were also made with regard to the influence of decomposing animal excreta upon the test, compared with tests made one hundred feet distant from the first, or from any such element of contamination. Observations also were made to determine the effect of excess of humidity upon the test; and, lastly, to determine the difference in the quantity of active oxygen present in the atmosphere of a malarious region with that of an atmosphere in a non-malarious region, the same test being employed in both localities, and the observations being taken at the same hours of the day.

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*Michigan State Board of Health Report for 1880, page 285.

Many of these observations may be but repetitions of those made by other observers, but the information already obtained is only sufficient to act as an incentive to other investigators to continue their labors in this direction. If there is no veritable connection between the varying proportions of ozone or active oxygen and health or disease, inquiry should be continued until the proof of this fact is substantiated. If there is a relation, though slight, the solution of the problem is worthy of the most untiring study.

In experimenting to determine the proportion in the atmosphere of oxidizing elements bearing a relation to health and disease, it does not seem necessary to employ a test that will verify only the existence of a single factor like that of ozone. Oxygen in a state of activity, whether generated by electrical or other influences, from oxygen in a nascent condition, or from products that easily liberate oxygen in a state of activity, like the essential oils, peroxide of hydrogen, or resinous compounds, is the desired factor to be searched after by the sanitarian and etiologist. If the test detects compounds that in themselves produce a coloration of the test-paper, it appears equivalent to a determination of an equal amount of active oxygen.

Is ozone to be discovered as existing in dwellings?

Max Von Pettenkofer, of Munich, in an article in the Contemporary Review, entitled, "The Hygienic Influence of Plants," makes the following assertion in regard to the relation of ozone to the appearance or disappearance of disease; "But one fact which was observed from the first, shows that it cannot be so; for the presence of ozone can never be detected in our dwellings, not even in the cleanest and best ventilated. Now, as it is a fact that we spend the greater part of our lives in our houses, and are better than if we lived in the open air, the hygienic value of ozone does not seem so very great."

Such a declaration, proceeding from such an influential origin, would, if erroneous, lead to many false deductions. That it is incorrect, the succeeding exhibit of the results of observations taken by myself, appears to prove. The observations were made with Schœnbein's test, moistened before exposure. The apartment where the experiments were made was well constructed, and a free circulation from the external air permitted, when there was the greatest coloration, allowing motion to the air and access of moisture. Where least coloration occurred every avenue to the external air was closed as much as possible.

EXHIBIT A.

Date.	Internal Observation.		External Observations.		Remarks.
1880.	Night.	Day.	Night.	Day.	
June 10	....	1	....	3.5	All numbers correspond to scale of 10 degrees of coloration.
" 11	0	1	2	3	
" 12	1	2	2.5	3	
" 13	2	2.5	3.5	3	
" 14	1	1	3.5	3	Strong wind.
Average.	1	1.5	2.9	3.1	

During the winter, in a north room of my own dwelling, where an effort was made to exclude the factor of ventilation, a coloration of three degrees was obtained. The temperature of the room was fifteen degrees Fahr., and a strong wind was blowing from the north. Externally a coloration of nine degrees was obtained. At the same time, in another north room of the same house, where the temperature amounted to seventy degrees Fahr., a distinct trace was discernible. At another time, when the external air was quiet, there was obtained one degree of coloration in the first room, where the temperature was forty-five degrees Fahr., and in the second room no coloration, with a temperature of seventy degrees Fahr. These results would suggest that a certain amount of motion of the air exceeding that usually existing in dwellings, would be auxiliary to conditions producing a manifestation of the presence of ozone therein. That the excess of moisture *externally* over that in the *interior* of dwellings is not a factor to be considered, seems proved by experiments made by the writer in regard to effects of moisture on the test as existing in dwellings. It was found that in rooms ventilated, when the external air was not disturbed by the influence of storms, the amount of moisture (absolute humidity) internally was equal to the amount of moisture externally, and that there was sometimes an excess of moisture in the interior of a dwelling over that exterior, when the amount of ozone was slight or entirely absent in the dwelling.

It is probable that sunshine is a condition aiding the production of ozone in dwellings, as more ozone was present during the day than night.

Prof. R. C. Kedzie says: "Ozone is doubtless formed in every sunlit room, and by its formation and destruction a vast amount of *materies morbi* may be destroyed, and it is no satisfactory proof that it is of no worth or influence because no residual ozone remains to act upon our test-paper."

Just what the influence upon the test is that is produced by the presence of carbon compounds, it is difficult to express. That its presence may modify the results of an experiment to ascertain the amount of ozone present is possible. To determine if the presence of pure carbonic acid would decolorize a slip of test-paper, already colored by exposure, I subjected a moistened slip to an atmosphere of carbonic acid by collecting the same over a pneumatic trough. On the gas being washed by passage through water the color upon the slip remained unaltered. On subjecting it to the influence of the gas as it escaped unwashed from the generator, a decolorization immediately occurred. This was found to be due to the presence of sulphurous acid.

Smoke is an element that will decolorize a slip of the test-paper already charged with liberated iodine. It is probable that the volume of smoke that usually, though imperceptibly, escapes from the stove, contains some property, perhaps that of sulphurous acid, that causes a change in the iodine as rapidly as it is liberated, resulting in the formation of a colorless iodate. To demonstrate the effect of gases, or smoke, generated by the stove, I introduced a glass tube through an opening of the stove into the midst of burning coals, and into the outer extremity of the tube I placed some of the test-paper already colored by the action of ozone. The result was a marked loss of the color on the paper. That this was not due to the action of increased temperature was proved by exposing a similar paper to the action of the same temperature at other points.

Although it is apparent that the amount of ozone in dwellings is actually less than that in the external air, it is also true that there exist agents that at present prevent an accurate estimate from being obtained by Schœnbein's test. That active oxygen bears to organic life—to physiological and pathological conditions—some essential relation, is a proposition yet open for discussion. To declare that its presence in dwellings is not proved is apparently an error. Even were it absent from dwellings, that circumstance could not prove its non-relation to health or disease. Without endeavoring to court discussion upon this important subject, it seems plausible to the writer that no oxygen enters the blood in any other state than as active oxygen. It may be that the large area of the alkaline pulmonary secreting surface, subject to the results of continuous evaporation, is in a condition to effect a generation of sufficient active oxygen to supply the blood with that which it requires. The excess in the external atmosphere may be of importance to the individual when a decrease in the external temperature intuitively directs him to take less deep inspirations than the warmer and drier atmosphere of the dwelling demanded, thus rendering the labor of the lungs less in supplying a given quantity of oxygen to the blood. If it should be objected that the ratio of active oxygen necessary to sustain the physiological requirements of the blood is not constant, I would inquire if the ratios of most meteorological conditions are constant.

During portions of the months of March and April, 1878, while the ground was frozen, and part of the time overspread with snow, I secured a record of observations of the amount of ozone in a small pine forest, about eight miles distant from my usual point of observation. The following exhibit represents the comparative amount existing at both places at the same time:

EXHIBIT B.

Date. 1878.	Pine Forest.		Open Country.		DATE, 1878.	Pine Forest.		Open Country.	
	Night	Day.	Night	Day.		Night	Day.	Night	Day.
March 4	6	5	8	4	March 20	4	5	5	3
" 5	6	5	6	4	" 21	5	4	4	4
" 6	6	5	4	5	" 22	5	4	8	5
" 7	6	5	10	8	" 23	5	5	5	5
" 8	4	4	8	7	" 24	4	6	4	6
" 9	5	4	5	4	" 25	5	5	5	5
" 10	5	5	8	4	" 26	5	5	5	5
" 11	5	5	6	8	" 27	4	4	8	5
" 12	5	5	10	9	" 28	4	4	9	8
" 13	6	5	10	9	" 29	4	5	8	4
" 14	4	5	8	9	" 30	5	5	4	4
" 15*	2	4	1	4	" 31	5	5	9	8
" 16	5	5	10	8	April 1	5	5		7
" 17	5	5	9	10	" 2	5	4	5	3
" 18	4	5	9	8	" 3	4	3	4	3
" 19	6	5	8	7					
					Average	4.80	4.70	6.93	5.90

*Frost on night ozonoscope.

Note.—Night observations, from 9 P. M. to 7 A. M,; day observations, from 7 A. M. to 2 P. M.

It is generally believed that ozone, or that product nearly identical in its nature, the peroxide of hydrogen, exists in excess amidst coniferous vegetation over that found in most other regions, but the above exhibit presents results contrary to that which ought to be expected to exist. This difference is, no doubt, in a great degree due to the time of year being when there was the least development of vegetable products, to the more confined circulation of the air, and perhaps to excess of humidity. The ground was low.

During the preceding summer, in the months of August and September, I secured the results of observations taken in the same pine forest, as represented in the following exhibit:

EXHIBIT C.

DATE. 1877.	PINE FOREST.		OPEN COUNTRY.		DATE. 1877.	PINE FOREST.		OPEN COUNTRY.	
	Night	Day.	Night	Day.		Night	Day.	Night	Day.
Aug. 26	3	4	1	4	Sept. 11..........	0	1	1	2
" 27	4	3	3	4	" 12..........	2	3	3	3
" 28	0	1	0	1	" 13..........	0	3	0	2
" 29	3	4	2	3	" 14..........	0	4	0	3
" 30	1	3	1	2	" 15..........	3	3	2	3
" 31	4	2	3	4	" 16..........	2	3	2	3
Sept. 1	4	4	4	3	" 17..........	4	4	3	4
" 2	1	4		3	" 18..........	3	4	1	4
" 3	3	3	3	4	" 19..........	3	4	2	4
" 4	3	4	3	4	" 20..........	1	3	1	2
" 5	2	3	2	3	" 21..........	1	4	1	3
" 6	3	3	3	4	" 22..........	2	3	0	3
" 7	1	4	1	4	" 23..........	3	4	1	3
" 8	1	3	1	3	" 24..........	3	2	3	3
" 9	1	4	1	4	" 25..........	1	2	2	3
" 10	3	1	3	3	Average..........	2.09	3.13	1.80	2.16

In the above exhibit we find a considerable difference in the two averages of night ozone, that found in the pine forest being in excess. The variation in the amount of ozone ascertainable during the day was slight. Were a sanitarium to be established in the vicinity of a pine forest for the sake of the salubrity of its immediate atmosphere it would appear expedient to consider other elements liable to affect the health, than ozone alone.

EXHIBIT D.

DATE. 1877.	COAL PITS.		OPEN COUNTRY.		DATE. 1877.	COAL PITS.		OPEN COUNTRY.	
	Night	Day.	Night	Day.		Night	Day.	Night	Day.
Aug. 1	2	3	2	4	Aug. 12..........	2	3	3	4
" 2	1	2	1	2	" 13..........	2	3	3	4
" 3	1	3	1	4	" 14..........	1	3	3	4
" 4	1	2	0	3	" 15..........	1	3	2	4
" 5	1	3	1	4	" 16..........	1	5	1	2
" 6	2	4	4	4	" 17..........	2	3	1	3
" 7	1	3	2	3	" 18..........	1	3	0	4
" 8	1	4	3	3	" 19..........	1	2	1	4
" 9	1	4	2	4	" 20..........	2	2	1	4
" 10	2	3	3	4	" 21..........	1	2	2	4
" 11	1	4	0	3	Average	1.33	3.00	2.71	3.57

Exhibit D records the results of observations taken in the borders of a pine forest, but in close proximity to coal-pits, as compared with those taken at a distance and free from any known cause of local disturbance to the test.

The heavy night air at the pits was surcharged with smoke that during the daytime was less concentrated. The results of the observations at this point were, at night, almost negative, although recorded as one degree of coloration whenever a trace was discernible. The negative results obtained here are accounted for by the presence of the discolorizing carbonaceous elements of the atmosphere associated with the element of excess of humidity. It does not seem unreasonable to conclude that the quantity of ozone present in an atmosphere subjected to the above mentioned influences, cannot be determined by the employment of Schœnbein's test.

During the construction of these coal-pits, in the year preceding these experiments, the amount of sickness at, and near to, them was very great. In a population amounting to one hundred and fifty, nearly one-fourth were simultaneously afflicted with fevers of a periodic type. Clay and porous soils were being overturned for the first time, and large belts of timber were being felled, opening avenues for swamps and ponds. The greatest prevalence of sickness was during the burning of some of the pits first constructed. The season during which the observations were taken was marked by a diminution in the number of cases of fever.

Another month's observations taken at the same place gave results almost identical to those above given.

The following exhibit represents the comparative amount of ozone existing over a swamp two miles from the point where the observations were taken with which they are compared. They were also taken simultaneously with those observations relating to the quantity of ozone existing in a pine forest.

EXHIBIT E.

Date. 1877,	Over Swamp.		Point free from such Influences.		Date, 1877.	Over Swamp.		Point free from such Influences,	
	Night.	Day,	Night.	Day.		Night.	Day.	Night.	Day,
Aug. 26	1	2	1	4	Sep, 10	0	0	3	3
" 27	1	2	3	4	" 11	0	1	1	2
" 28	1	1	0	1	" 12	0	3	3	3
" 29	1	3	2	3	" 13	0	1	0	2
" 30	1	1	1	2	" 14	0	2	0	3
" 31	4	5	3	4	" 15	2	2	2	3
Sept, 1	0	1	4	3	" 16	1	2	2	3
" 2	0	0	3	3	" 17	0	3	3	4
" 3	0	1	3	4	" 18	0	1	1	4
" 4	0	3	3	4	" 19	....	....	2	4
" 5	0	1	2	3	" 20	0	5	1	2
" 6	0	1	3	4	" 21	0	4	1	3
" 7	0	1	1	4	" 22	0	0	0	3
" 8	0	3	1	3					
" 9	0	5	1	4	Av'ge,	0,44	1.92	1.78	3.17

In the above exhibit a great difference is seen to exist between the averages of the two points of observation.

Whether this difference is due to the emission of gases destructive to a large portion of the atmospheric ozone naturally present, or whether the same interferes with a deposition of liberated iodine, or whether the apparent absence is due to an excess of moisture sufficient to decolorize the paper, are inquiries that can only be determined by experimentation. The excess of humidity naturally present at such a point appears to offer some explanation.

The experiments over the swamps were made by suspending slips of test-paper about three feet above the soil. They were exposed to a free circulation of the air, but protected from the sunlight. During the time these observations were being taken the several families residing near this swamp suffered more or less from frequent attacks of periodic fever.

With a view to ascertain the comparative results of observations for the presence of ozone as it existed at two differing points of elevation, fifty-four observations were conducted at the elevations of four and fourteen feet from the ground.

The following exhibit contains the results of these observations:

EXHIBIT F.

	Higher Elevation.		Lower Elevation.		Remarks.
	Night	Day.	Night	Day.	
	4	9	7	9	Rain all day.
	8	8	9	7	Rain all day.
	7	7	8	8	Rain all day.
	9	5	8	5	Rain in night.
	4	4	8	6	Rain in morning.
	7	5	8	5	Rain all day.
	4	5	5	6	Fair.
	5	5	6	5	Fair.
	4	3.5	4	3.5	Fair.
	4	3.5	3	3.5	Rain in night, paper lost color.
	1	4	2	4	Fair.
	2	3	2	3	Fair.
	3.5	....	3.5	....	Fair.
	1	4	3.5	4	Fair.
Average.	4.53	5.07	5.50	5.30	

These observations do not demonstrate that actually a greater quantity of ozone was present in the lower stratum of the air than in the upper. The variation of the degree of moisture at the two points may lead to an explanation; yet the excess of ozone at the lower plane seemed to correspond with the presence of aqueous precipitation and a consequent pulverization of the rain-drops. This might have led to the generation of ozone by increase of electrical influences, as spoken of by Fox in his work on "ozone."

At the suggestion of Dr. Baker, I directed my attention to the relative quantity of ozone existing near decomposing animal excreta as compared with that found one hundred feet distant from any such contaminating influence.

EXHIBIT G.

Date, 1879.	Impure Air.		Pure Air.	
	Night.	Day.	Night.	Day.
June 9	2.5	3.5	4.5	3.5
" 10	2	2.5	3.5	3.5
" 11	1	3	2	3
" 12	2	2.5	2.5	3
" 13	3	....	3.5	
" 14	3	3	3.5	3
Average	2.3	2.9	3.3	3.2

Both ozonoscopes were suspended at a distance of six feet from the ground, and both were subjected to the influence of the same degree of atmospheric humidity. It is therefore probable that the variation in the degree of coloration was due to the exposure of one ozonoscope to the influences of rapidly oxidizing effete material.

In considering the influences existing that might have occasioned an error in the results of the observations recorded in the foregoing exhibits, none is more apparent than that of excess of moisture. Some atmospheric conditions associated with twenty observations where there was a total absence of coloration are shown in the succeeding exhibit :

EXHIBIT H.

Number of Case.	Lowest Temperature.	Velocity of Wind—Miles per Hour.	Relative Humidity	REMARKS.
1......	44	2	75	Few clouds.
2......	37	2	96.6	Cloudy. Frost on test-paper.
3......	34	2	96.6	Frost.
4......	32	2	96.6	Slightly cloudy.
5......	32	2	96.6	Slightly cloudy.
6......	32	2	96.6	Slightly cloudy.
7......	32	2	96.6	Slightly cloudy.
8......	25	2	100	Slightly cloudy.
9......	41	2	96.6	Slightly cloudy.
10......	45	12	100	75 per cent. of clouds. Heavy dew.
11......	44	2	100	Heavy dew.
12......	57	2	100	Smoky,—75 per cent. of clouds.
13......	44	2	85	Heavy dew.
14......	44	2	100	Heavy dew. No clouds.
15......	44	2	100	Heavy dew.
16......	59	2	100	Heavy fog,—50 per cent. clouds.
17......	46	2	96.6	Heavy fog,—75 per cent. clouds.
18......	49	2	96.6	Heavy dew. No clouds.
19......	25	2	100	Frost. No clouds.
20......	57	2	96.6	90 per cent. clouds.

The above cases represent nearly all those of complete obliteration of color occurring during a period of three years. *These all occurred during the night observation.* With each case there was nearly, or quite, a complete saturation of the atmosphere with moisture.

In one hundred and forty-three observations taken by myself to determine the relative value of Schœnbein's test when exposed to the air dry, and when exposed after having been previously moistened, I discovered an excess of coloration in the dry slip over that of the wet slip forty times, the largest excess being five degrees of coloration. During these forty instances the sky was covered with one hundred per cent. of clouds. In only six instances in the whole number of observations was the wet slip colored in excess of the dry when there was one hundred per cent. of clouds. When there was less than seventy-five per cent. of clouds the *moistened* slip was more greatly colored than the dry. While I at one time thought it possible that some electrical phenomena might be a cause of the ozonoscopic conditions just mentioned, I am now disposed to believe the cause to bear relation more to hygrometric states influenced by the varying per cent. of clouds. A *dry* slip is exposed to the influençes of these conditions, and a gradual deposition of the moisture upon the same aids rather than retards the coloration. But when a *moistened* slip is exposed to the influences of these conditions of the atmosphere it is liable to become blanched as fast as the iodine is deposited. Cornelius B. Fox says: "If the iodine of starch be so slightly soluble in water, how does it happen that these tests often and rapidly become, when they are wet, completely blanched? If a deeply tinted Negretti's test be cut into small portions and placed in a little distilled water, some difficulty will be experienced in rendering the fragments colorless. Many hours, and perhaps a day or two will elapse before all color is removed from them. If, on the other hand, a colored Negretti's test be kept in a moist condition with distilled water, conducted to it by a fine thread of lamp-wick or darning-cotton, the color will rapidly disappear. In the latter experiment the iodide of starch becomes vaporized from the test."

It is thus proved that in more than one-fourth of the cases where observations are taken with Schœnbein's test, providing the same proportion of days all cloudy existed as above illustrated, the dry slip will exhibit the greatest coloration, and in the remaining cases the deepest tint would be exhibited by means of the wet slip.

Through the kindness of a friend residing in Litchfield county, of the State of Connecticut, I was enabled to secure results of ozonometric observations among its non-malarious hills, during the summer of the year 1878. The record of these observations is presented in the following exhibit in comparison with the record of observations taken at this point, where periodic fevers prevail:

EXHIBIT I.

Date, 1878.	Litchfield County, State of Connecticut.		Otisville, Michigan.		Date, 1878.	Litchfield County, State of Connecticut.		Otisville, Michigan.	
	Night.	Day.	Night.	Day.		Night.	Day.	Night.	Day.
Aug. 6	4	5	3	3	Sept. 9	0	2	4	2
" 7	4	4	3	3	" 10	0	3	2	3
" 8	3	3	3	4	" 11	0	4	2	2
" 9	4	6	3	4	" 12	2	3	....	3
" 10	4	4	3	4	" 13	1	3	4	4
" 11	3	4	1	1	" 14	0	2	4	1
" 12	3	4	* 0	3	" 15	2	3	1	2
" 13	1	3	3	3	" 16	0	2	5	3
" 14	0	2	4	3	" 17	0	3	2	3
" 15	0	3	4	3	" 18	0	3	3	3
" 16	2	3	4	3	" 19	....	3	....	3
" 17	2	3	1	3	" 20	2	2	3	4
" 18	2	4	1	3	" 21	1	2	3	3
" 27	0	3	† 0	3	" 22	2	3	1	3
" 28	1	3	3	3	" 23	0	2	3	2
" 29	1	3	4	4	" 24	0	2	3	4
" 30	1	2	1	4	" 25	2	3	3	3
" 31	0	3	3	4	" 26	1	2	4	3
Sept. 1	3	2	3	2	" 27	3	2	§ 1	2
" 2	0	2	4	3	" 28	1	3	3	3
" 3	0	3	4	4	" 29	0	3	4	2
" 4	2	1	3	3	" 30	0	2	4	2
" 5	4	1	‡ 0	3	Oct. 1	0	2	3	1
" 6	2	3	‡ 0	3	" 2	2	3	4	3
" 7	0	2	4	4	" 3	3	3	3	2
" 8	1	3	4	2	Avr'ge.	1.38	2.82	2.77	2.90

* Heavy dew in morning.
† Great amount of moisture in night.
‡ Fog in morning.
§ Frost in morning.

The small quantity of ozone exhibited for the night in the record obtained from Connecticut impresses one with the belief that some atmospheric conditions existed that failed to testify to the actual amount of ozone present. Excessive moisture appears to have been one of these conditions, as reported by the observer to me.

As local conditions greatly affect the test for ozone, the observations that might be taken in other parts of this mountainous country might present results more in unison with the popular belief that active oxygen exists in greatest quantities amidst the mountains.

As spoken of, the velocity of the wind, if it is great, and the air is saturated with moisture, will occasion a decolorization of the test-paper unless protected from its influence. But if a test-paper be exposed to the free action of the wind when the air is not saturated with moisture a greater coloration will often occur than when *protected* from the action of the wind.

COLORATION OF BOTH SIDES OF THE TEST-PAPER.

Although Schœnbein's test is considered the most reliable in use for the detection of ozone, something yet remains to be done in order to render even this test perfect, exclusive of the effects of such conditions as already have been mentioned.

In the manufacture of the test-paper I use, only one side of it is covered with the preparation that by chemical alteration and change of color enables us to estimate the relative amount of ozone present. In this connection Dr. H. B. Baker remarks that "Some test-paper prepared in Germany, examined by me, seemed to be like Swedish filter-paper; it was of loose texture, and on exposure was soon colored on both sides alike, but the degree of coloration was more uniform under varying conditions than it is on the paper used by the observers in Michigan. The loose texture paper seemed to be exceedingly prone to take on a color equaling from 2 to 4 on our scale, but did not seem to be as ready to show shades above or below those. On comparing it with our paper, it was found to fade quicker after being moistened, and I came to believe that it was not so accurate as is ours for the purpose of indicating the relative qualities of ozone in the atmosphere." In examining the test-paper, after exposure, I have frequently found that the side of the paper upon which there was none of the preparation, exhibited the greater coloration. To determine, if possible, the cause of this, I recorded in a series of observations, as shown in the following exhibit, the degrees of coloration that appeared upon both sides of the paper. In the first series the number of observations was 34. In 19 of these observations there was the deeper coloration on the side not having the preparation on it. The same degree of coloration occurred upon both sides at once in 13 instances. There was a deeper coloration on the side containing the compound of starch and iodide of potassium, twice:

EXHIBIT K.

First Series of Observations on the Influence of Relative Humidity upon the Coloration by Ozone of Both Sides of the Test-paper.

	COLORATION, MARKED ON A SCALE OF 10°.		RELATIVE HUMIDITY.—PER CENT. OF SATURATION OF THE AIR AT THE BEGINNING OF THE EXPOSURE WHEN THE COLORATION WAS AS SPECIFIED.			
	On Front of Test-paper.	On Back of Test-Paper	All Observations in the Series.	Greatest Color on Front of Paper.	Same Color on Both Sides.	Greatest Color on Back of Paper.
	2	2	82.3	....	82.3	....
	1	2	95.3	....	....	95.3
	2.5	3	95.3	....	....	95.3
	2	3	76.0	....	....	76.0
	2	3.5	84.2	....	....	84.2
	2.5	3.5	76.0	....	....	76.0
	2.5	3.5	74.9	....	....	74.9
	2.5	3.5	87.1	....	....	87.1
	1	2	100.0	....	....	100.0
	3.5	3	89.3	89.3	....	....
	1.5	2.5	81.4	....	....	81.4
	3.5	3.5	100.0	....	100.0	....
	3	3	100.0	....	100.0	....
	2	3.5	76.9	....	....	76.9
	2.5	2	100.0	100.0	....	....
	3.5	3.5	100.0	....	100.0	....
	2	3	53.7	....	....	53.7
	2.5	3.5	87.1	....	....	87.1
	2	2	93.2	....	93.2	....
	3	3.5	86.4	....	....	86.4
	3	4	85.8	....	....	85.8
	2.5	2.5	92.6	....	92.6	....
	3	3	92.8	....	92.8	....
	2.5	3.5	86.6	....	....	86.6
	2.5	3.5	93.1	....	....	93.1
	3	3.5	71.0	....	....	71.0
	3.5	3.5	100.0	....	100.0	....
	3	3	94.4	....	94.4	....
	3	3	100.0	....	100.0	....
	2.5	2.5	95.0	....	95.0	....
	3	3.5	85.8	....	....	85.8
	3	3	80.5	....	80.5	....
	1.5	2.5	69.4	....	....	69.4
	2.5	2.5	100.0	....	100.0	....
Total.....	85.5	102.5	2986.1	189.3	1230.8	1566.0
Av'rages	2.51	3.01	87.8	94.7	94.7	82.4

Assistant Professor F. S. Kedzie, of the Agricultural College, at Lansing, Mich., suggests that these conditions may appear from the existence of a thin film, or tough pellicle, sometimes formed over the starch compound, thus preventing the access and ready action of ozone in setting free the iodine; the degree of coloration varying according to the condition of the surface of the test-paper, and according to certain conditions of atmospheric humidity existing at the time of the exposure of the test.

It is probably true that varying conditions of moisture have a marked influence with other influences producing the results referred to.

In sixteen of the nineteen instances where there was a deeper tint on the back of the paper the relative humidity was less than ninety per cent., ranging from fifty-three per cent. upwards. In three instances where there was the deeper tint upon the back the relative humidity exceeded ninety per cent. In only one instance did the relative humidity mount to one hundred per cent. In only three instances out of the fifteen when the front had a coloration equal to that upon the back of the test-paper, or a greater coloration, the relative humidity was less than ninety per cent. In twelve instances when the coloration upon the front was equal to, or greater than that upon the back, the relative humidity exceeded ninety per cent. In seven of the fifteen instances when the degree of coloration on the front was equal to, or greater than, that upon the back, the relative humidity was one hundred per cent. This would seem to prove that conditions of moisture have a decided influence in affecting the phenomena in question.

After an exposure of the test-paper for a time sufficient to produce a coloration, if there is a deeper tint upon the back than on the front side a removal of a thin portion of the starch from the front will not disclose as deep a tint as there is upon the back, nor will as marked a coloration appear in front until all the starch is removed, when both sides of the paper exhibit the same degree of discoloration.

The paper which is used in preparing the test readily absorbs a portion of the solution of iodide of potassium contained in the starch compound, and on exposure to oxidizing elements exhibits chemical change as well as the prepared starch. The difference in the texture of the paper itself from the texture of the starch compound would suggest the existence, in the paper and compound, of differing qualities for the absorption of moisture.

An *average* degree of moisture seems to be a condition rendering the paper saturated with a solution of iodide of potassium in starch-water a more delicate test than the starch and iodide of potassium test. Where *excess* of moisture obtains, the starch and iodide of potassium test appears to be the most reliable.

The preceding exhibit does not contain an extensive series of observations as we would wish to have in order to establish conclusive evidence, but was all we had at the time of writing the foregoing. Since that time additional observations have been made, and the results are shown in the following exhibit:

EXHIBIT L.

Second Series of Observations on the Influence of Relative Humidity upon the Coloration by Ozone of Both Sides of the Test-paper.

	Coloration, Marked on a Scale of 10°.		Relative Humidity—Per Cent. of Saturation of the Air at the Beginning of the Exposure when the Coloration was as Specified.			
	On Front of Test-paper.	On Back of Test-paper.	All Observations in the Series.	Greatest Color on Front of Paper.	Same Color on Both Sides.	Greatest Color on Back of Paper.
	3.5	3.0	100.0	100.0	....	....
	3.0	3.5	85.8	....	....	85.8
	3.5	4.5	75.5	....	....	75.5
	2.5	3.0	86.2	....	....	86.2
	1.5	3.0	83.4	....	....	83.4
	4.0	4.0	100.0	....	100.0	....
	3.5	3.0	100.0	100.0	....	....
	5.0	4.0	91.3	91.3	....	....
	3.5	2.5	85.8	85.8	....	....
	2.0	3.0	74.5	....	74.5	....
	2.0	3.5	75.9	....	....	75.9
	3.0	3.0	84.0	....	84.0	....
	3.0	3.0	91.4	....	91.4	....
	3.5	4.0	83.4	....	....	83.4
	3.0	2.5	83.4	83.4	....	....
	7.0	3.0	93.1	93.1	....	....
	3.0	2.0	100.0	100.0	....	....
	8.0	3.0	91.4	91.4	....	....
	3.0	2.5	91.6	91.6	....	....
	4.0	2.5	100.0	100.0	....	....
	3.0	2.5	100.0	100.0	....	....
	3.0	3.0	90.6	....	90.6	....
	2.5	4.0	100.0	....	....	100.0
	3·5	3.5	100.0	....	100.0	....
	4.0	4.5	79.3	....	....	79.3
	2.5	2.5	92.6	....	92.6	....
	2.5	3.0	84.0	....	....	84.0
	3.0	3.0	100.0	....	100.0	....
	4.0	3.0	92.6	92.6	....	....
	2.0	3.0	79.3	....	....	79 3
	2.5	3.0	69.6	....	....	96.6
	3.5	2.5	93 2	93.2	....	....
	3.0	3.0	100.0	....	100.0	....
	4.0	3.5	92.6	92.6	....	....
	3.5	3.5	100.0	....	100.0	....
	8.0	6.0	100.0	100.0	....	....
	6.0	5.0	90.5	90.5	....	....
	3.5	2.5	100 0	100.0	....	....
	3.0	4.0	83.4	....	....	83.4
Totals...	139.5	128.5	3524.8	1605.5	933.1	986.2
Average	3.58	3.29	90.4	94.4	93.3	82.2
Av. of both ser.	3.08	3.16	89.2	94.5	94.1	83.2

In the foregoing exhibit the statement of the relative humidity is made for the time when the test-paper was put out for exposure. In nearly all the cases where there was *less* coloration on the back of the paper than on the front, and a relative humidity of *less* than ninety per cent. at the time the test-paper was put out, the relative humidity was over ninety per cent. when the paper was compared with the scale, showing that there was an increase of moisture after the paper was first exposed.

When the back of the paper was the most deeply colored, and on its first exposure the relative humidity was more than ninety per cent. (another exception to the general rule), there was almost always a considerable decrease in the relative humidity.

SUGGESTIONS FOR IMPROVED METHODS OF OBSERVATIONS.

Negative results obtained by the exposure of Schœnbein's test-paper in dwellings seem to be due as much to elements affecting the liberated iodine as to absence of ozone. This test, then, seems to be of little use in determining the presence of ozone in dwellings.

Valuable as are the general results of ozonometric observations, it is obvious that many of them are clouded with error. How to remove these errors is a subject important to all those interested in the study of ozonometry as to its meteorological, physiological, or pathological relations. Much study is yet necessary before the best methods for accurately estimating the quantity of ozone present at any time in the atmosphere will be determined. In the use of Schœnbein's test, in order to obtain the maximum results of an observation where it is necessary to guard against excess of moisture, the exposure of a dry and wet slip at the same time, would appear to be a proper method to adopt; also to suspend them at such points as where the condensation of vapor would be least liable to occur. To make the period of time less for the exposure of test-paper would be another means to obtain maximum results of an observation.

It is well known that by increased velocity of the wind more ozone may be carried to a given point than there would be if the velocity were less. To determine the quantity of ozone, therefore, liable to affect the health of an individual subjected to the influence of rapid currents of air, it is desirable to expose the test-paper to the same current. But the loss of the liberated iodine as a result of such exposure, suggests that in order to obtain the *deepest* coloration the slip must be protected from too great velocity of the wind, especially when there is an excess of moisture in the atmosphere.

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